forests

Article

Assessment and Distribution of Damages Caused by the Trunk-Boring Insects *Coraebus undatus* (Fabricius) (Coleoptera: Buprestidae) and *Reticulitermes grassei* Clément (Blattodea: Rhinotermitidae) in Mediterranean Restored Cork-Oak Forests

Ana M. Cárdenas [1,*], Dafne Toledo [2], Patricia Gallardo [1] and José Guerrero-Casado [1]

[1] Department of Zoology, Campus Rabanales, University of Córdoba, E-14071 Córdoba, Spain; b42gatop@uco.es (P.G.); b32gucaj@uco.es (J.G.-C.)
[2] Department of Genetics, Instituto Universitario de Biotecnología y Biomedicina (BIOTECMED), Universitat de València, E-46100 Burjassot, Spain; dafne.toledo@uv.es
* Correspondence: ba1cataa@uco.es

Abstract: This work assesses damage caused by *Coraebus undatus* (Fabricius) (Coleoptera: Buprestidae) and *Reticulitermes grassei* Clément (Blattodea: Rhinotermitidae) in managed cork oak forests from the southern Iberian Peninsula. Lesions were diagnosed and quantified in relation to the following features: height and orientation in the trunk, diameter at breast height, solar exposure, understory presence and orography. The distribution patterns of lesions in the study area across 12 plots and in the trunk of the trees were also analyzed. The study was performed in "Sª de Hornachuelos" Natural Park (Córdoba, Spain) and the research area encompassed 12 environmentally-restored sampling plots. Data were recorded from 2007 to 2014, with yearly sampling from late June to mid-September, corresponding to the cork extraction period, since lesions caused by these insects are well distinguishable promptly after bark removal. The results reveal that *C. undatus* has low population levels and a non-uniform distribution pattern in the study area as well as in the trunk of the tree. It shows preference for medium height but not by any trunk orientation. *R. grassei* also shows low infestation levels and a preference to affect the trunk's base. Comparatively, *C. undatus* showed higher infestation levels than *R. grassei.* The location of damage was also different, since galleries made by *C. undatus* predominated at intermediate trunk heights while those of *R. grassei* were more frequent at lower heights. Our results further showed a low co-occurrence of both species in the same tree trunks, which could be explained in terms of overlapping in the distribution areas of both species. These results provide background information that will enable natural resources managers to detect changes and trends of these species and inform future management decisions.

Keywords: buprestids; Coleoptera; cork-oak; damage; dehesa; *Quercus suber*; Rhinotermitidae; subterranean termites; wood-boring insects

Citation: Cárdenas, A.M.; Toledo, D.; Gallardo, P.; Guerrero-Casado, J. Assessment and Distribution of Damages Caused by the Trunk-Boring Insects *Coraebus undatus* (Fabricius) (Coleoptera: Buprestidae) and *Reticulitermes grassei* Clément (Blattodea: Rhinotermitidae) in Mediterranean Restored Cork-Oak Forests. *Forests* **2021**, *12*, 1501. https://doi.org/10.3390/f12111501

Academic Editor: Manuela Branco

Received: 20 July 2021
Accepted: 29 October 2021
Published: 30 October 2021

1. Introduction

The Spanish term "dehesa" refers a modified agroforestry landscape, with very low tree density and well-developed pasture, resulting from the clearing of the Mediterranean scrubland and forests. In dehesas, diverse *Quercus* species can coexist, *Quercus ilex* L. (holm oak) and *Quercus suber* L. (cork oak) being the most abundant. The clearing of shrubs is performed to facilitate the development of herbaceous plants, which are then grazed upon by cattle [1]. It is estimated that there are about 5.8 million ha of dehesa occupying the central western and southwestern areas of Spain. The dehesas are of a great economic value and are also important in terms of biodiversity. For this reason, they have been included in the plan of complementary measures of the Agricultural Policy of European Community to enable sustainable exploitation, allowing the conservation of this unique agroecosystem [2,3].

Diverse assemblages of insects are associated with Quercus species in dehesas [4] either as carpophages, folivores or xylophages [5]. Particularly, the incidence of xylophagous insects depends, among other factors, on environmental features and the overall health of the tree [6]. Among the xylophagous insects, boring species belonging to the Buprestidae (Coleoptera), Cerambycidae (Coleoptera) and Rhinotermitidae (Blattodea) families predominate [7,8]. Particularly, the species involved on this study are the cork oak (*Q. suber* L.) and two woods boring insect: *Coraebus undatus* (Fabricius) (Coleoptera: Buprestidae) and *Reticulitermes grassei* Clément (Blattodea: Rhinotermitidae).

Cork oaks are large trees with a thick bark commonly called 'cork' that typically occur primarily in the southwestern Iberian Peninsula [9]. When this bark is extracted for commercial use, the trunk shows a peculiar reddish tone. Cork oaks are spread between the Thermo- Mediterranean and the Supra-Mediterranean belts and show affinity to siliceous, loose and permeable substrates typical of hygrophilous environments. Although there exist pure or almost pure formations of *Q. suber*, this species can be also integrated in mixed *Quercus* formations, where can coexist with diverse species such as *Q. ilex* an *Quercus faginea* (Lamarck), maintaining the typical physiognomy of the dehesa [10].

The conservation status of dehesas is threatened, among other factors, by the progressively more evident "decline syndrome", which consists in the development of a set of decay symptoms that occur without a fixed pattern but following a sequential chronology. The main causes of this decline have been categorized in three groups which act synergically [11]:

I. Predisposing factors to which the trees are permanently exposed, such as harsh climatic conditions, edaphic changes and inadequate silvicultural practices;
II. Aggravating factors which act during a short but intense period of exposure, including the action of defoliating insects such as the Lepidoptera *Lymantria dispar* (L.) and *Tortrix viridana* L. and insect borers such as *C. undatus* (our study subject);
III. Contributing factors, which cause death of poor health or weakened trees, such as pathogenic fungi of the genus *Phytophthora* and *Pythium*.

During the last decades, the decline of *Quercus* spp. has affected millions of specimens throughout their distribution area [12], which has got a great economic repercussion, lessening the cork production between 40% and 89%, depending on the geographical zone. The cork oaks affected by this syndrome are more vulnerable to suffer the attack of pathogens, defoliators and xylophages.

Adults of *C. undatus* are diurnal, thermophiles and herbivorous oligophagous [13]. The adults emerge in spring from inside of trunks and main branches, causing exit holes "D" shaped in the bark. The females lay eggs on the bark surface or within cracks. After hatching, the neonatal larvae move towards the phloem and begin to feed by constructing characteristic tunnels. Usually, the larva goes through four stages before winter and, after the last phase, the larva remains in a quiescent state or pupa until late spring, when it emerges as an adult [14].

Although *C. undatus* can feed on several *Quercus* species, its damages produce greater economic losses in the case of the cork oaks. During their development, they elaborate sinuous feeding galleries in the phellogen layer, reaching even 2 m length and 3–4 mm width, harming the regenerative capacity of the tree [4]. In the following years, it could be observed that the new layers of cork show hypertrophied areas corresponding to the galleries filled with excrements. These scars, commonly called 'cork shingles' due to its sinuous morphology (Figure 1a), significantly devalue the cork price, thus threatening the sustainable exploitation of cork-oaks forests [15]. Factors influencing the presence of *C. undatus* are tree density, presence of understory, age, health and height of trees, solar orientation and drought stress [16]. Like in the case of other borers, the control of *C. undatus* is difficult to perform because the larva (damaging stage) is endophytic, undetectable and practically inaccessible [17,18].

(**a**) (**b**)

Figure 1. Lesions in *Q. suber* trunk performed by boring insects. (**a**) "cork shingles" by *C. undatus*, in which three interceptions are visible; (**b**) "chicken feet" by *R. grassei*, with one interception visible.

In Andalusia (southern Iberian Peninsula), several studies have been carried out on the environmental variables that influence the incidence of *C. undatus*. On this regard, Soria et al. [19] point out that the infestation degree is directly related to the type of dehesa, being more abundant in cork oak forests with medium or high tree density and with woody understory. Another factor also affecting is the age of the trees, probably because these buprestids are attracted by the healing substances exuded after cork extraction. This practice is not carried out in young cork oaks, which have smaller trunks diameter [15]. Drought stress also entails a greater infestation risk. Under these conditions, damage can reach 70% of infected trees, showing the greatest number of galleries in the most sun exposed areas [19].

The other species considered in this study is *R. grassei*, a subterranean termite native from Andalusia, which has been expanding for the remaining Iberian territory [20]. This species is one of the greatest biological risks for the wooden structures of buildings. Populations and damages have been increasing in the Mediterranean and Cantabrian coasts, as well as in the inner Iberian Peninsula [21]. The trophic activity of termites has been described in several forest and crops ecosystems, such as pines, fruit trees, eucalyptus and oaks [22,23]. Gallardo et al. [8] identified, described and quantified damages by *R. grassei* in *Q. suber*. The lesions (Figure 1b) are sinuous galleries ranging from a few centimeters up to more than half a meter length. These lesions are commonly known as "chicken feet" due to the characteristic shape of their galleries. High incidence of *R. grassei* in cork oaks, could facilitate the infection by pathogens and other stressor organisms [24,25] harming the tree health. In addition, these lesions could reduce the cork price, another factor endangering the sustainability of dehesa [8]. However, only punctual data about the occurrence of *R. grassei* in cork-oak forests in the Southern Iberian Peninsula are available in the literature [8].

This study has been focused on these two insect species because their lesions depreciate the value of cork, thus threatening the sustainable exploitation of dehesas.

This work is integrated in the research Project "Study and Monitoring Plan of Wood-Boring beetles from *Quercus* species", encompassed in the Compensatory Measures Program linked to the construction of the Breña dam (92/43/EEC Habitat Directive of the

European Council for the conservation of natural habitats and wildlife). The affected area has undergone to an Environmental Restoration Program [26].

In the context defined by the previous information, the present work was aimed with the following specific objectives:

1. To provide a frame of reference that will allow to detect changes over time on the incidence and the distribution of *C. undatus* and *R. grassei* in the study area after the implementation of the restoration program;
2. To establish differences in the trunk height and orientation selected to be attacked by each boring species;
3. To discern if some environmental features (understory, solar orientation and orography) could influence the existence of damage caused by these insects;
4. To determine if the presence of one of the trunk-boring species facilitates the infestation by the other one.

2. Materials and Methods

2.1. Study Area

The study area is located in the "Sierra de Hornachuelos" Natural Park (Córdoba, southern Iberian Peninsula), occupies 60,032 ha and has a great biological interest due to the diversity of animals and plants harbored. Hence, it has been included in diverse environmental protection programs, such as the Inventory of Natural Protected Areas of Andalusia [27], Biosphere's Reserve "Dehesas de Sierra Morena" (Man and Biosphere Program of UNESCO), the Special Protection Zone for Birds (ZEPA, Birds Directive 79/409/EEC) and Special Conservation Area (SCA) by the Habitat Directive (92/43/EEC).

In addition, the study area is integrated in the Environmental Recovery Program linked to the construction of Breña dam (in compliance with the Directive Habitat, Council Directive 92/43/EEC). It comprises a total of twelve restoration plots, where several measures for conservation have been implemented, including reforestation with *Q. ilex, Q. suber* and *Q. faginea* [28].

Overall, the area shows a wavy relief, with altitudes ranging from 100 to 725 m.a.s.l. The soils are physical and chemically homogeneous, mostly acids and with low levels of organic material and carbon [27]. The climate is typically Mediterranean, the landscape is dominated by a Mediterranean mixed sclerophyllous forest, sited on the thermo- and meso- Mediterranean bioclimatic belts [8].

The vegetation in the area belongs to the Duriilignosa formation, represented in the Iberian Peninsula by the *Quercetea ilicis* type. These sclerophyllous forests are characterized by the predominance of holm oaks (*Q. ilex*) and cork oaks (*Q. suber*) [29], as well as *Pistacia lentiscus* L., *Asparagus albus* L., *Arbutus unedo* L. and different species of *Erica* sp. and *Cistus* sp. in the bushes [30].

2.2. Field Sampling

The field sampling was carried out between 2007 and 2014, in a total of 12 sampling plots (P1 to P12 in advance; Table 1) submitted to a restoration program. Data were recorded from June to mid-September each year, fitting to the cork extraction periods, since the galleries made by these insects are easier to detect during the first weeks after cork-boring practices. In general, the cork removal rotation is allowed every 11 years in Andalusia. Directive relative to the frequency and procedure of the cork extraction tasks in Andalusia are set out in the Official Bulletin of the Andalusian Regional Government (https://www.juntadeandalucia.es/boja/1988/79/index.html accessed on 14 June 2021). The chronology of recording data in each sampling plot and year was as follows: Year 2007: P2, P5, P6; Year 2009: P7, P8, P9, P10; Year 2011: P1, P3; Year 2013: P4; Year 2014: P11, P12.

Table 1. Site name, code, environmental features (undergrowth, solar orientation, orography) and UTM (Universal Transverse Mercator) coordinates and for each of the sampling plots. "All": orientation to all winds.

Nomination	Code	Understory	Orientation	Orography	UTM Coordinates
Mesas Bajas	P1	Present	All	Hillside	30S03204190
Las Mesas	P2	Present	All	Valley	30S03204120
Cerro del trigo	P3	Absent	All	Valley	30S03214190
Llanos de Iglesia	P4	Present	South	Hillside	30S03204121
Los Baldíos	P5	Present	East	Hillside	30S03304122
Las Tonadas	P6	Present	Southwest	Valley	30S03504123
Loma de Jarales	P7	Absent	S	Hillside	30S03204199
Parralejo	P8	Absent	Northwest	Valley	30S03104326
MataRomán	P9	Present	All	Hillside	30S03204197
Navalcastaño	P10	Absent	All	Hillside	30S03254203
Los Lagares	P11	Absent	All	Hillside	30S03204190
Mezquitillas	P12	Present	South	Valley	30S03180190

The number of trees sampled in each plot varied depending on the availability of uncorked trees, up to a maximum of 50. A total of 381 trees were examined. The damages were quantified by the number of lesions observed in the uncorked area of the trunk. Four levels of height measured from the ground (Level 1: from 0 to 0.5 m; Level 2: above 0.5 to 1 m; Level 3: above 1 to 1.5 m; Level 4: above 1.5 to 2 m) and four sections corresponding to the north, south, east and west solar orientations [31] were differentiated.

The typology and design of the galleries made by each species conditioned the way they were quantified. The lesions caused by *C. undatus* were counted following the method proposed by Soria et al. [19], considering the number of intersections of distinguishable galleries in the trunk sections defined by each level and orientation. To record the damage caused by *R. grassei,* which is more branched and more localized, the number of full lesions were counted at each height level and orientation sections.

Each sampled tree was geo-referenced and the following parameters were measured [32]:

- Understory: Presence/absence of understory under the canopy;
- Orientation: south (135–225°), north (315–45°), east (45–135°), west (225–315°), all the winds (if none of the above orientations dominated);
- Orography (terrain slope): valley or hillside;
- Diameter at breast height (DBH) obtained from the trunk perimeter measured at breast height (≈1.3 m) (Table 2);
- Uncorking height.

Table 2. Number of cork oaks corresponding to each plot**;** average diameter breast height (DBH) in cm; standard deviation (±SD) and tree estimated age [3].

Sampling Plot	Number of Trees	DBH ± SD	Estimated Age
P1	45	53.46 ± 12.96	Mature tree
P2	19	75.39 ± 19.06	Aged tree
P3	50	57.11 ± 20.13	Mature tree
P4	39	57.23 ± 13.19	Mature tree
P5	14	36.9 ± 12.07	Mature tree
P6	18	39.81 ± 12.68	Mature tree
P7	33	38.6 ± 12.08	Mature tree
P8	39	56.5 ± 17.98	Mature tree
P9	35	41.06 ± 24.12	Mature tree
P10	36	55.90 ± 23.01	Mature tree
P11	18	67.45±13.50	Mature tree

P12	35	39.81 ± 12.68	Mature tree

2.3. Damages Quantification

The incidence of *C.undatus* and *R. grassei* were obtained from appraisal their respective damages. The indices considered in both cases were the following:

- Tree Damage Intensity (DI) defined according to the following expression [19]:

$$\mathrm{DI} = \frac{\text{Total number of gallery intersections}}{4\text{ x (number height levels showing damages)}}$$

where 4 is the number of orientation sections;

- Plot Infestation Rate (PI): $\sum \mathrm{DI}/n$ where n is the number of damaged trees in each sampling plot [33];
- The percentage of damaged cork oaks (PD) in each sampling plot in relation to the total of sampled trees.

To make a more accurate interpretation of the incidence, DI and PI values were typified according to the criteria displayed in Table 3 [25].

Table 3. Incidence estimated from the combination of tree damage intensity (DI) and plot infestation rate (PI) indexes.

DI and PI	Damage Level
0	Absent
>0–0.5	Very low
>0.5–1.0	Low
>1.0–1.5	Medium
>1.5–2	High
>2	Very high

2.4. Data Analysis

The correlation between PD (percentage of damaged cork-oaks) and PI (plot infestation rate) was assessed for *C. undatus* and *R. grassei,* separately, by Spearman correlation, since both variables did not fit a normal distribution.

Four different generalized linear mixed models (GLMM) were used to assess which factors influencing tree damage intensity (DI) which was treated as response variable. The differences in the trunk orientation and height area selected to be attacked by *C. undatus* were assessed by two different GLMMs, using the tree and the plot as random factors and the height level (four levels) was included as independent categorical variable in the Model-1, whereas the orientation (five levels) was included as independent categorical variable in the Model-2, respectively. In both models, a negative binomial distribution was used to take into account data overdispersion.

Moreover, another two GLMMs were carried out to assess the effect of the independent variables orography (valley/hillside), trunk perimeter, understory (presence/absence), solar orientation and cork extraction height on the tree damaged intensity (response variable) caused by *C. undatus* (Model-3) and *R. grassei* (Model-4) separately, including the plot as a random variable in both models. We also used a negative binomial distribution to consider data overdispersion. The post hoc tests (Fisher LSD with Bonferroni corrections) within the mixed analysis were developed to check for significant differences among the level of categorical variables. Because of the small number of trees damaged by *R. grassei*, 25 trees with no damage were randomly selected from the overall sample to be included in the Model-4 and no statistical analyses were performed to check differences between the four height levels and the four orientations. All the statistical analysis were carried out using Info-Stat software [34].

3. Results

3.1. Incidence of C. undatus and R. grassei

Of the total trees showing some kind of damage by wood boring insects, 188 (88.26%) were only affected by *C. undatus,* whereas 22 trees (10.23%) had exclusively damages caused by *R. grassei* and only 5 trees (2.34%) shared damages by both species. Of the 381 examined trees, 49.3% were not damaged by *C. undatus* and 50.7% had some amount of damage by this boring beetle, which was present in nine of the twelve sampling plots. Only P1, P6 and P11 are free of lesions. In addition, most of them showed a very low damage level. Detailing the data of tree damage intensity (DI), the greater percentages correspond to those showing a very low damage level (Figure 2).

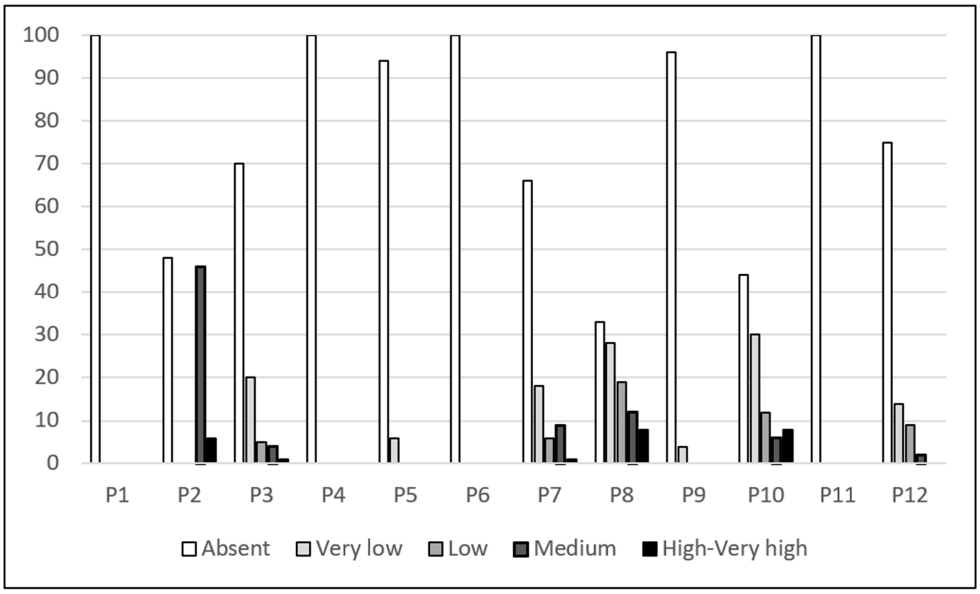

Figure 2. Incidence of *C. undatus* in percentage of trees per plot (P) showing different damage intensity.

There are, however, some plots with an important proportion of trees reaching the high or very high levels as P2, P8 and P10.

Regarding the values of the Plot Infestation rate, it ranges from 0.01(±0.008) to 2.70 (±0.371) (Table 4), covering the whole range of variation, although in most cases, the rate remained at minimum levels of damage. The highest incidence was recorded in P2, where up to 12 lesions were detected in two of the trees sampled, whereas only one or two galleries were present in the rest of the trees.

Table 4. Incidence of *C. undatus* estimated from Plot Infestation rate (PI), the percentage of damaged cork oaks (PD) in relation to the total sampled trees and to the damage level obtained in each sampling plot (P). SD = standard deviation.

Coraebus undatus			
Sampling Plot	**PI ± SD**	**PD (%)**	**Damage Level**
P1	0	0	Absent
P2	2.70 ± 0.371	58	Very high
P3	0.22 ± 0.430	30	Very low
P4	0.06 ± 0.206	6	Very low
P5	0.01 ± 0.030	4	Very low
P6	0	0	Absent
P7	0.17 ± 0.454	34	Very low

P8	0.45 ± 0.626	66	Very low
P9	0.01 ± 0.061	4	Very low
P10	0.37 ± 0.520	56	Very low
P11	0	0	Absent
P12	0.01 ± 0.008	2	Very low

Concerning to the percentage of infested trees (PD), there were also large differences between plots, corresponding to P2, P8 and P10 the highest values (>50%), P3 and P7 had intermediate values (30 and 34 %) and in the other plots the values were below 10% (Table 4). If the values of PI and PD are jointly analyzed, there is a significant correlation between PI and PD (Spearman correlation $\varrho = 0.81$; p-value= 0.0013), although the P2 showed a high PI value in relation to its PD value.

In the study of the incidence of *R. grassei*, we proceeded in a similar way as for *C. undatu*s. The results showed that there is little or no incidence in most of the surveyed plots (Figure 3). Of the examined trees with data of *R. grassei*, most of them had no damages (91.7%) and only 22 trees (5.8%) showed galleries caused by this species. Only in P5 and, slightly, in P10, some trees reached the low level of infestation.

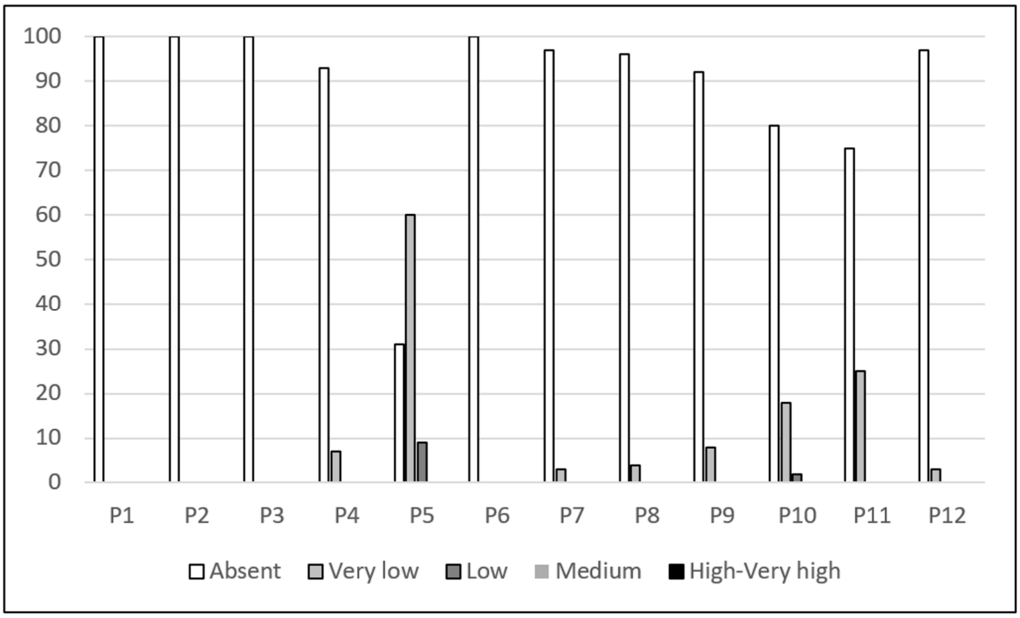

Figure 3. Incidence of *Reticulitermes grassei* in percentage of trees per plot (P) showing different damage intensity.

A similar result was obtained when analyzing the rates of Plot infestation (PI) and Percentage of damaged trees (PD), with a high correlation between both parameters (Spearman correlation $\varrho = 0.99$; $p < 0.0001$). In relation to the latter value, only in P5 more than half of the sampled cork oaks showed termite's lesions (Table 5). Overall, the damage rates were low and the level of incidence in the whole study area can be classified as very low.

Table 5. Incidence of *R. grassei* referred to the plot infestation index (PI), the percentage of damaged cork oaks (PD) in relation to the total sampled trees and to the damage level obtained in each sampling plot (P). SD = standard deviation.

	Reticulitermes grassei		
Sampling Plot	**PI± SD**	**PD (%)**	**Damage Level**
P1	0	0	Absent
P2	0	0	Absent

P3	0	0	Absent
P4	0.006 ± 0.206	6	Very low
P5	0.241 ± 0.170	68	Very low
P6	0	0	Absent
P7	0.002 ± 0.012	2	Very low
P8	0.003 ± 0.015	4	Very low
P9	0.014 ± 0.060	8	Very low
P10	0.059 ± 0.152	20	Very low
P11	0.035 ± 0.068	25	Very low
P12	0.001 ± 0.009	2	Very low

3.2. Selection of the Trunk Area to Be Attacked by C. undatus and R. grassei

The Model-1 showed significant differences ($F = 5.24$; $p = 0.0013$) concerning the damage recorded in the four height levels, with greater values in levels 2 and 3 (Table 6). The Model-2 did no find significant differences of the damage by *C. undatus* between the four solar orientations ($F = 0.54$; $p = 0.6552$) (Table 6).

Table 6. Number of damaged trees by *C. undatus* and their proportion according to the four damaged height levels and the four orientations separately. DI = Tree Damage Intensity. SE = standard error of means. Small cases letter showed significant differences according to the *post hoc* tests.

	No. Damaged Trees	Proportion of Damaged Trees (%)	DI (mean ± SE)
		Height Level	
Level 1	119	63.29	0.52 (±0.07) b,c
Level 2	142	75.53	0.82 (±0.10) a,b
Level 3	131	69.68	0.95 (±0.12) a
Level 4	87	46.37	0.55 (±0.08) c
		Orientation	
North	119	63.29	0.63 (±0.08)
South	135	71.8	0.70 (±0.09)
East	119	63.29	0.78 (±0.10)
West	117	62.23	0.72 (±0.10)

With respect to *R. grassei*, the greatest proportion of lesions were observed in the lower levels (1 and 2) and in the south orientation (Table 7). Nevertheless, the statistical comparison was not significant in any case.

Table 7. Number of damaged trees by *R. grassei* and their proportion according to the four damaged levels and the four orientations separately. DI = Tree Damage Intensity. SE = standard error.

	No. Damaged Trees	Proportion of Damaged Trees (%)	DI (mean ± SE)
		Height Level	
Level 1	15	68.18	0.101 (±0.03)
Level 2	14	63.63	0.090 (±0.03)
Level 3	8	36.36	0.060 (±0.03)
Level 4	4	18.18	0.015 (±0.01)
		Orientation	
North	9	40.9	0.064 (±0.03)
South	13	59.1	0.098 (±0.03)
East	6	27.3	0.045 (±0.02)
West	8	36.4	0.060 (±0.02)

3.3. Effect of the Environmental Features on Damage Caused by C. undatus and R. grassei

The Model-3 and Model 4 showed that the environmental variables had no significant effect on the damaged caused by *C. undatus* and *R. grassei* in the study area (Table 8).

Table 8. Results of the generalized linear models (Model-3 and Model 4) using the Tree Damage Intensity index as response variables; denDF = degree of freedom of the denominator.

	Model-3 (*C. undatus)*			**Model-4 (*R. grassei)***		
Variable	**denDF**	**F-Value**	***p*-Value**	**denDF**	**F-Value**	***p*-Value**
Undergrowth	98	0.52	0.4726	39	0.11	0.7406
Orientation	98	0.42	0.7972	39	0.12	0.9938
Orography	98	0.33	0.5682	39	0.23	0.6368
Trunk perimeter	98	0.53	0.4668	39	0.34	0.5636
Uncorking height	98	0.35	0.5551	39	0.04	0.8497

3.4. Coexistence of Damage Caused by Both Boring Species

The analyses of the damage distribution in the cork oaks classified according to the categories no damaged, damaged by only one of the species or damaged by both species, indicated that 45.81% of the cork oaks were free of damage. Among the damaged trees, lesions caused only by *C. undatus* predominated (affecting 49.30% of the total surveyed trees) while only 5.89% had galleries made exclusively by *R. grassei*. The percentage of cork oaks damaged by both species is less than 1% of the total. Only five trees were damaged by both species simultaneously (four in P10 and one in P8). It is worth mentioning some of the observations made in the field: those cork oaks damaged simultaneously by *C. undatus* and *R. grassei* had diameters comprises between 65 and 89 cm, corresponding to mature-aged trees. It was observed that *C. undatus* reached the 4 hight level, coexisting most cases in the same trunk area with the lesions of *R. grassei* but these were at lower levels (1, 2 and 3). As for the orientation of the lesions, the two types of galleries were present at any orientation except in the eastern, where damage by the termite was not observed.

4. Discussion

Sustainable conservation of dehesas is challenged by two main processes: the predictable effect of climate change and the expansion of the *Quercus* decline syndrome [35]. The effect of climate change on Mediterranean oaks species has been analyzed from chorological [36] eco-physiological [37,38] and phytosanitary [6] viewpoints. Other more indirect and long-term aspects, such as forestalling the disturbing effects of climate change on herbivory and activity of pathogens [39] have been also analyzed. Indeed, global warming influences life patterns, distribution [40] and plant interactions of phytophagous insects [41], thus favoring pest spreading, increasing the severity of damages, or widening the distribution areas.

Related to the *Quercus* decline syndrome, there is a consensus that the process is triggered by the synergistic action of abiotic, biotic and anthropogenic factors and as a consequence, trees become more vulnerable to pests and pathogens, feeding back into the process [12]. It is also well known that the insects linking their biological activity to bark and wood decisively intervene in the oaks decline process [42,43], including some xylophagous species of boring beetles such as *C. undatus*. Although these insects are part of the natural dynamics of forest ecosystems, the weakened phytosanitary condition of decaying oaks could trigger demographic explosions, which directly or indirectly could cause death of trees because the severity and profusion of lesions [6]. Moreover, in the case of cork oaks, the cork extraction tasks also stress and weak the trees, facilitating outbreaks of these insects [44,45]. It has been proved a relationship between cork extraction and the number of galleries caused by the larva of *C. undatus* [25]. On this sense, monitoring phytophagous insect has been proposed as a valid tool for assessing the impact and sustainability of forestry practices [46]. Under this framework, this research provides a reference dataset on the incidence and the distribution of *C. undatus* in a restored oak forest located in the Hornachuelos Natural Park, which would allow to detect changes over time.

Previous research [25] shows that C. undatus is a very common phytophagous insect in Andalusia, affecting more than 90% of the sampled forests and over 70% of trees. Similar results were obtained in Catalonia [47] and in the Valencian region [48]. Although these infection rates are high, according to the literature [25], the intensity of the damage is relatively low and the level of damage fluctuates from low to very low. Our results are consistent with this information, indicating even a minor incidence. There are, however, some plots with significant percentages of trees reaching the high or very high levels of damage intensity. This result may be related to the age of the trees. At least in P2, some cork oaks with larger trunk perimeters have greater number of lesions. However, relatively large cork oaks were present in P11, but this plot was free of damage. In relation to the percentage of infested trees, there are also differences be-tween plots, but in most cases, approximately half of the sampled trees were affected. If the values of plot infestation rate and percentage of damaged cork oaks are jointly analyzed, there was a general positive correlation between both parameters, although in some cases, the plot with the highest infection rate (P2) does not coincide with the plot showing the highest proportion of damaged trees (P8). These results suggest a non-homogeneous distribution of damages neither between plots, nor between trees within the same plot. Similar results were obtained by Jiménez et al. [25], who mentioned that many boring insects select the most stressed trees (with presence of pathogens or pests) [49], or those corresponding to certain genetic varieties more susceptible to be attacked [50].

About the location of the lesions, the literature states that the damage is more frequent at 0.5 to 1.5m height [48,51]. The results obtained in our study corroborate this preference, being the height levels 2 (0.5–1m) and 3 (1–1.5m) the most recurrently attacked. Cyclical cork removing is often carried out in these height ranges, which may facilitate the entry of neonate larvae into the inner cambium [25]. Concerning to the solar orientation, previous research suggests a tendency to colonize sunnier areas in in southern exposure [25,51]. This preference is shared by other bark-boring insects [52,53] and is explainable by the thermophilic nature of Buprestidae [54]. However, in our work this tendency was not noticed.

As regards the characteristics of the cork oaks, the variable perimeter as a proxy for tree age [55], indicated that most of the sampled and most of the affected trees were of intermediate age. Thus, the age of the cork oak is not a decisive factor to suffer the attack of the insect, in agreement with the results of Gallardo [51] and in contrast to the results of Soria et al. [15], Suñer and Abós [47] and Bernal Cardillo [56]. On this concern, it has been reported that some buprestids species such as *Coraebus florentinus* (Herbst; Coleoptera: Buprestidae) selects aged trees [51,57]. The environmental parameters considered (understory, orography, cork extraction height) neither significantly affected the probability of infestation by *C. undatus*. These results contrast with previous works, which found a positive relationship between high incidence of *C. undatus* and abundant understory [19,40,48,54]. This fact is explained in terms of providing more feeding resources and suitable habitats for adults [58], as well as shelter from predators [59].

The second wood borer species addressed in this study was *R. grassei*, a subterranean termite species whose lesions to cork oak was described recently [8]. Boring activity of termites in dehesas has not been later published except for a paper about the activity in the field and the extent of the foraging area [60]. Indeed, the lack of information on termite's incidence in other forest areas is a shortcoming for the interpretation of the results. In any case, it is important to highlight that *R. grassei* only affected 5.8% of the sampled cork oaks, with little or no incidence in the sampled plots, agreeing with data provided by Gallardo et al. [8]. The low level of damage per tree is likely because during the foraging activity the termites contact diverse food sources. Unlike *C. undatus* larva, which feeds during their whole life on the same cork oak, *R. grassei* colonies can feed on several trees simultaneously [61].

In relation to the location of the lesions, those of *R. grassei* tend to be concentrated at the basal levels (0–1m). This result is because of the subterranean life way of this species [62], whose foraging activity progresses from the soil upwards. A priori, it is expected that lesions would be in the northern section of the trees due to the affinity of subterranean termites for humid habitats [63]. Nevertheless, the results obtained do not corroborate this statement. This inconsistency may be related with the occurrence of understory growing close to the damaged cork oaks, since vegetation reduces surface water runoff and helps water to be infiltrate into the soil [64]. Therefore, soil moisture could be a more decisive factor than the orientation itself for the presence of the termite. The effects of other environmental variables were not significant either.

The analysis of the association of the lesions caused by both species shows that, in those plots where they coexist, the buprestid has higher levels of infestation (approx. 50% vs 6%, respectively). In most of the trees surveyed there is no association between the damage caused by the two species. R. grassei infests more frequently the basal areas of the trunk due to its subterranean habits, while the females of C. undatus reach the trunk by flying to lay the eggs on the bark, at a greater height [14].

Regarding the solar orientation of lesions, no fixed pattern was observed. However, in the trees with many lesions of both species, these are in any orientation except for the eastern one where R. grassei is absent. The coexistence of several species of saproxylic insects has been reported in the literature [65]. When the populations are large it is reasonable to hypothesize that the amount of available resource decreases and coexistence is a form of sharing it. When the population levels are low (as our case), it might be worth considering that previous infestation by one harmful agent triggers a response of releasing volatile substances to scar the cork oak, which can attract other boring insects [66]. In this sense, previous research performed in the study area found that many oak specimens were affected by the Quercus decline syndrome, as well as a high incidence of carpophagous and xylophagous [3]. If this weakened state were the main explaining the coexistence of these species, more trees showing both types of galleries should be in the research plots. So, it is more probable that the coexistence of C. undatus and R. grassei is the result of the overlapping distribution areas.

At first, the most plausible interpretation of the results would be to rule out such association and, therefore, that the coexistence of lesions in the same cork oak is prob-ably circumstantial. More prospective studies that provide sufficient data are needed to determine whether there are association between these species.

Summarizing, this work assesses damages by C. undatus and R. grassei in restored dehesas from the southern Iberian Peninsula. The results provide background information that will enable to detect future changes and trends of these potential pests, which is essential for taking management decisions.

Author Contributions: Conceptualization, A.M.C. and D.T.; Data collection, A.M.C. and P.G.; Statistical Analyses J.G.-C.; writing—original draft preparation, D.T. and A.M.C.; writing and editing, A.M.C.; Review, J.G.-C. and A.M.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Ingeniería y Gestion del Sur I. P.A. SEVILLE. SPAIN: 12009-042 and the University of Cordoba, Spain.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank Esteban Alcántara (ETSIAM, University of Córdoba) for his comments which have contributed to a substantial improvement of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Acosta, R. Medio ambiente, grupos sociales y conocimiento local en la dehesa: Un caso de estudio en la Sierra Morena extremeña. *Rev. Esp. Estud. Agrosoc. Pesq.* **2005**, *206*, 63–86.
2. Fragoso, R.; Marques, C.; Lucas, M.R.; Martins, M.B.; Jorge, R. The economic effects on common agricultural policy on Mediterranean montado/dehesa ecosystem. *J. Policy Model.* **2011**, *33*, 311–327.
3. Cárdenas, A.M.; Gallardo, P.; Hidalgo, J.M. Medidas compensatorias del proyecto del embalse de la Breña II: Estudio sobre coleópteros perforadores de Quercíneas, Informe. University of Córdoba-IPA, Córdoba, Spain, Unpublished work, 2014.
4. Romanyk, N.; Cadahia, D. *Plagas de Insectos en las Masas Forestales Españolas. Colección Técnica;* Ministerio de Agricultura, Pesca y Alimentación, ICONA: Madrid, Spain, 1992; 342p.
5. Foahom, B. *Insect Pest Incidence on Timber Tree Species in Natural Forest in South Cameroon*; The Tropenbos-Cameroon Programme, Kribi, Tropenbos-Cameroon Documents 12 European Commission; University of Wageningen: Wageningen, The Netherlands, 2002; 54p.
6. Navarro, R.M.; Fernández, P. *El Síndrome de la Seca en el Encinar. Propuesta de Solución para el Valle de los Pedroches*; Editorial Fundación Ricardo Delgado Vizcaino: Córdoba, Spain, 2000.
7. Cárdenas, A.M.; Ocete, M.E.; Soria, F.J. Datos sobre la presencia de *Coroebus undatus* (Fab.) y *Coroebus florentinus* (Herbst) en el alcornocal del Parque Natural de la Sierra de Hornachuelos (Sª Mª Central). In Proceedings of the III Jornadas Científicas de la Sociedad Española de Entomología Aplicada, Villava, Navarra, Spain, 19–21 November 1991; pp. 9–14.
8. Gallardo, P.; Cárdenas, A.M.; Gaju, M. Ocurrence of *Reticulitermes grassei* (Isoptera: Rhinotermitidae) on cork oaks in the Southern Iberian Peninsula: Identification, description and incidence of the damage. *Sociobiology* **2010**, *56*, 675–687.
9. Díaz-Fernández, P.; Jiménez, M.P.; Catalán, G.; Martín, S.; Gil, L. *Regiones de Procedencia de Quercus suber L.*; Editorial ICONA: Madrid, Spain, 1995; 99p.
10. Rivas Martínez, S. *Memoria del Mapa de Series de Vegetación de España 1:400.000*; Ministerio de Agricultura, Pesca y Alimentación, ICONA: Madrid, Spain, 1987; 270p.
11. Vivas, M.; Cubera, E.; Moreno, G.; Solla, A. The decline of *Quercus ilex* and *Q. Suber* in the Iberian Peninsula. In *Agroforestry Systems as a Technique for Sustainable Land Management*; AECID Unicopia Ediciones: Madrid, Spain, 2008; 247p.
12. Tiberi, R.; Branco, M.; Bracalini, M.; Croci, F.; Panzavolta, T. Cork oak pest: A review of insect damage and management. *Ann. For. Sci.* **2016**, *73*, 219–232.
13. Füsternau, B.; Quero, C.; Ma Riba, J.; Rosell, G.; Guerrero, A. Field trapping of the flathead oak borer *Coroebus undatus* (Coleoptera: Buprestidae) with different traps and volatiles lures. *Insect Sci.* **2015**, *22*, 139–149.
14. Lieutier, F.; Day, R.K.; Battisti, A.; Grégaire, J.-C.; Evans, F.H. *Bark and Wood Boring Insects in Living Trees in Europe, a Synthesis*; Springer: Orléans Cedex, France, 2007; 568p.
15. Soria, F.J.; Villagrán, M.; Ocete, M.E. Estudios poblacionales sobre *Coroebus undatus* (Fabricius) (Coleoptera, Buprestidae) en alcornocales de Andalucía Occidental. I: Relación infestación-bosque. *Bol. Sanid. Veg. Plagas* **1992**, *18*, 377–383.
16. Toledo, D. *Análisis de la Coexistencia de Daños por Reticulitermes grassei Clement (Isoptera) y Coraebus undatus Fab. (Coleoptera) en el Alcornoque (Quercus suber L.), Trabajo Fin de Máster en Biodiversidad: Conservación y Evolución*; University of Valencia: Valencia, Spain, 2017; 51p.
17. Hajek, A.E.; Bauer, L.S. Microbial control of wood-boring insects attacking forest and shade trees. In *Field Manual of Techniques in Invertebrate Pathology;* Lacey, L.A., Kaya, H.K., Eds.; Springer: Secaucus, NJ, USA, 2007; pp. 505–533.
18. Liu, H.; Bauer, L.S. Microbial control of emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae) with *Beauveria bassiana* strain GHA: Greenhouse and field trials. *Biol. Control* **2007**, *45*, 124–132.
19. Soria, F.J.; Villagrán, M.; Del Tío, R.; Ocete, M.E. Estudios prospectivos de los principales perforadores del alcornoque en la Sierra Norte de Sevilla. *Bol. Sanid. Veg. Plagas* **1994**, *20*, 643–651.
20. Barambio, A. Isoptera. In *Diploma de Especialización Profesional Universitario en Control de Plagas Animales en Ambiente Urbano, Módulo III, Control de Insectos (I)*; Selfa, J. Ed.; University of Valencia, Títulos Propios de Postgrado a Distancia: Valencia, Spain, 2012; pp. 30–69.
21. Valentín, N. *Análisis de Biodeterioro. Infestaciones y su Erradicación*; Unidad de Biodeterioro del IPHE: Madrid, Spain, 2002.
22. Osbrink, W.L.A.; Williams, K.S.; Connick, W.J.; Wright, M.S., Jr.; Lax, A.R. Virulence of bacteria associated with the Formosan subterranean termite (Isoptera: Rhinotermitidae) in New Orleans, LA. *Environ. Entomol.* **2001**, *30*, 443–448.
23. Mankin, R.W.; Osbrink, W.L.; Oi, F.M.; Anderson, J.B. Acoustic detection of termite infestations in urban trees. *J. Econ. Entomol.* **2002**, *95*, 981–988.
24. Quinto, J.; Marcos-García, M.A.; Díaz-Castelazo, C.; Rico-Gray, V.; Galante, E.; Micó, E. Association patterns in saproxylic insect networks in three Iberian Mediterranean woodlands and their resistance to microhábitat loss. *PLoS ONE* **2015**, *10*, e0122141.
25. Jiménez, A.; Gallardo, A.; Antonietty, C.A.; Villagrán, M.; Ocete, M.E.; Soria, F.J. Distribution of *Coraebus undatus* (Coleoptera: Buprestidae) in cork oak forests of Southern Spain. *Int. J. Pest Manag.* **2012**, *58*, 281–288.
26. Cárdenas, A.M.; Vargas, E.; Gallardo, P.; Pérez, S. Medidas compensatorias del proyecto de embalse de la Breña II: Estudio sobre coleópteros perforadores de Quercíneas, Memoria Final. University of Córdoba-IPA, Córdoba, Spain, Unpublished work, 2008.
27. Pinilla, R. *Plan de Ordenación de Recursos Naturales. Plan Rector de Uso y Gestión del Parque Natural de la Sierra de Hornachuelos;* Consejería de Medio Ambiente, Junta de Andalucía: Sevilla, Spain, 2006; 83p.

28. De Andrés, C.; Cosano, I.; Pereda, N. *Manual Para la Diversificación del Paisaje Agrario*; Consejería de Medio Ambiente, Junta de Andalucía, Comité Andaluz de Agricultura Ecológica (CAAE): Sevilla, Spain, 2003; 126p.
29. Cárdenas, A.M.; Gallardo, P. The effects of temperature on the preimaginal development of the jewel beetle, *Coraebus florentinus* (Coleoptera: Buprestidae). *Eur. J. Entomol.* **2012**, *109*, 21–28.
30. Torres, J. A.; Ruiz, J.M. *La Sierra de Hornachuelos. Colección Naturaleza y Medio Ambiente*; Editorial Almuzara: Córdoba, Spain, 2009; 160p.
31. Du Merle, P.; Attie, M. *Coraebus undatus* (Coleoptera Buprestidae) sur Chene-liege dans le sud-est de la France: Estimation des degats, relations entre ceux-ci et certains facteurs du milieu. *Ann. Sci. For.* **1992**, *49*, 571–588.
32. Calzado, M.C.; Fernández, R.P. *Manual para el Estado Sanitario de la Vegetación Arbórea de la Dehesa*; Junta de Andalucía, Consejería de Agricultura y Pesca-Consejería de Medio Ambiente: Córdoba, Spain, 2009; 248p.
33. Carrasco, A.; Rodríguez, S.; Suero, E.; Sánchez, M.F.; Ocete, M.E.; Villagrán, M.; Soria, F.J.; Jiménez, A.; Gallardo, A.; Antonietty, C. Informe sobre el diseño de un programa de control integrado en los principales insectos perforadores y carpófagos de la encina y el alcornoque en Andalucía. In Proceedings of the XXV Reunión Anual del Grupo de Trabajo Fitosanitario de Forestales, Parques y Jardines, Jaca, Huesca, Spain, 24 Novermber, 2008; pp. 129–139.
34. Di Rienzo, J.A.; Casanoves, F.; Balzarini, M.G.; Gonzalez, L.; Tablada, M.; Robledo, C.W. *InfoStat Versión 2020*; Editorial Brujas, Centro de Transferencia InfoStat, FCA, Universidad Nacional de Córdoba: Córdoba, Argentina, 2020; 253p.
35. Ogaya, R.; Liu, D.; Barbeta, A.; Peñuelas, J. Stem Mortality and Forest Dieback in a 20-Years Experimental Drought in a Mediterranean Holm Oak Forest. *Front. For. Glob. Chang.* **2020**, *2*, 89.
36. Benito-Garzón, M.; Sánchez de Dios, R.; Sainz, H. Effects of climate change on the distribution of Iberian tree species. *Appl. Veg. Sci.* **2008**, *11*, 1–10.
37. Gea-Izquierdo, G.; Martín-Benito, D.; Cherubini, P.; Cañellas, I. Climate-growth variability in Quercus ilex West Iberian open woodlands of different stand density. *Ann. For. Sci.* **2009**, *66*, 802–812.
38. Patón, D.; García-Herrera, R.; Cuenca, J.; Galavis, M.; Roig, F.A. Influence of climate on radial growth of holm oaks (*Quercus ilex* subsp. ballota Desf) from SW Spain. *Geochronometria* **2009**, *34*, 49–56.
39. Ayres, M.P.; Lombardero, M.J. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. *Sci. Total Environ.* **2000**, *262*, 263–286.
40. Alexander, K. Changing distributions of Cantharidae and Buprestidae within Great Britain (Coleoptera). In *Proceedings of the 13th International Colloquium of the European Invertebrate Survey, Leiden, The Netherlands, 2–5 September 2001*; Reemer, M., van Helsdingen, P.J., Kleukes, R.M.J.C., Eds.; 2003; pp. 87–91.
41. Bale, J.S.; Masters, G.J.; Hodkinson, I.D.; Awmack, C.; Bezemer, T.M.; Brown, V.K.; Butterfield, J.; Buse, A.; Coulson, J.C.; Farrar, J.; et al. Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores. *Glob. Chang. Biol.* **2002**, *8*, 1–16.
42. Thomas, F. Recent advances in cause-effect research on oak decline in Europe. *CAB Rev. Perspect. Agric. Vet. Sci. Nutr. Nat. Resour.* **2008**, *3*, 1–12.
43. Inácio, M.L.; Henriques, J.; Sousa, E. Contribution symbiotic fungi to cork oak colonization by *Platypus cylindrus* (Coleoptera: Platypodidae). *Silva Lusit.* **2011**, *19*, 89–99.
44. Cao, O.V.; Luciano, P. Severe infestations of *Platypus cylindrus* Fabricius (Coleoptera Platypodidae) in Sardinian cork oak forests. *IOBC/WPRS Bull.* **2005**, *28*, 145–146.
45. López-Pantoja, G.; Dominguez, L.; Sánchez-Osorio, I. Analysis of *Prinobius myardi* Mulsant population dynamics in a Mediterranean cork oak stand. *Ann. Société Entomol. Fr.* **2011**, *47*, 260–268.
46. Jactel, H.; Nicoll, B.C.; Branco, M.; Gonzalez-Olabarria, R.J.; Grodzki, W.; Långström, B.; Moreira, F.; Netherer, S.; Orazio, C.; Piou, D.; et al. The influences of forest stand management on biotic and abiotic risks of damage. *Ann. For. Sci.* **2009**, *66*, 701–701.
47. Suñar, D.; Abós, L. Estudio de la infestación de *Coroebus undatus* (Fabricius) (Col., Buprestidae) en los alcornocales catalanes. *Sci. Gerund.* **1994**, *20*, 45–53.
48. Soto, A.; Rivas, J.; Martínez, M.; Miravet, A. 2006. Coroebus undatus. In *Principal Problema en la Sanidad de los Alcornocales del Parque Natural de la Sierra de Espadán en la Comunidad Valenciana*; Universidad de Politécnica de Valencia, Departamento de Ecosistemas Agroforestales, ETSIA:Valencia, Spain, 2006; 10p.
49. Haavik, L.J.; Stephen, F.M.; Fierke, M.K.; Salisbury, V.B.; Leavitt, S.W.; Billings, S.A. Dendrochronological parameters of northern red oak (*Quercus rubra* L. [Fagaceae]) infested with red oak borer (*Enaphalodes rufulus* [Haldeman] [Coleoptera: Cerambycidae]). *For. Ecol. Manag.* **2008**, *255*, 1501–1509.
50. Andicoberry, S.; Arias, M.J.; Benítez, M.A.; Carrasco, A.; Ceacero, C.J.; Cordero, L.; Diaz, M.C.; Gimeno, D.; González, E.; Jiménez, M.E.; et al. 2007. *El alcornoque y el corcho en Andalucía*; Editorial Consejería de Medio Ambiente, Junta de Andalucía: Sevilla, Spain, 2007; 391p.
51. Gallardo, P. Incidencia de Coleópteros perforadores en formaciones de Quercíneas del suroeste peninsular: Evaluación de daños y propuestas para la conservación. Tesis Doctoral, Universidad de Córdoba: Córdoba, Spain, 2011; 230p.
52. Mouna, M.; Fabre, J.P. *Pest Insects of Cedars: Cedrus Atlantica Manetti. C. Libani A. Richard and C. Brevifolia Henry in the Mediaterranean Area*; Entomological Research in Mediterranean Forest Ecosystems; INRA Editions: Paris, France, 2005; 280p.
53. Sousa, E.; Inácio, M.L. New Aspects of *Platypus cylindrus* Fab. (Coleoptera: Platypodidae) Life History on Cork Oak Stands in Portugal. In *Entomological Research in Mediterranean Forest Ecosystems*; Lieutier, F., Ghaioule, D., Eds.; INRA Editions: Paris, France, 2005; 280p.

54. Cobos, A. *Fauna ibérica de coleópteros Buprestidae;* Editorial Consejo Superior de Investigaciones Cientificas: Madrid, Spain, 1986; 364p.
55. Plieninger, T.; Pulido, F.J.; Konold, W. Effects of land-use history on size structure of holm oak stands in Spanish dehesas: Implications for conservation and restoration. *Environ. Conserv.* **2003**, *30*, 61–70.
56. Bernal, C.; Cardillo, E. *Plagas y Enfermedades del Alcornocal: La Culebra del Corcho*; Cuadernos Forestales n.º 2; Instituto del Corcho, la Madera y el Carbón Vegetal (IPROCOR): Mérida, Spain, 2004; 6p.
57. Lombardero, M.J.; Fernández, F.J. Distribución y daños de *Coraebus florentinus* (Herbst) (Col. Buprestidae) en Galicia. *Ecología* **1996**, *10*, 499–508.
58. Montoya, J.M. *Los Alcornocales*; Ministerio Agricultura Pesca y Alimentación: Madrid, Spain, 1988; 251p.
59. Vodka, S.; Konivicka, M.; Cizek, L. Habitat preferences of oak-feeding xylophagous beetles in a temperate woodland: Implications for forest history and management. *J. Insect Conserv.* **2009**, *13*, 553–562.
60. Cárdenas, A.M.; Moyano, L.; Gallardo, P.; Hidalgo, J.M. Field Activity of *Reticulitermes grassei* (Isoptera: Rhinotermitidae) in Oak Forests of the Southern Iberian Peninsula. *Sociobiology* **2011**, *41*, 493–510.
61. Traniello, J.F.A.; Leuthold, R.H. Behaviour and Ecology of Foraging in Termites. In *Termites: Evolution, Sociality, Symbioses, Ecology*; Abe, T., Bignell, D.E., Higashi, M., Eds.; Kluwer Academic Publisher: Kota Kinabulu, Malasia, 2000; pp. 141–168.
62. Nobre, T.; Nunes, L.; Bignell, D.E. Tunnel geometry of the subterranean termite *Reticulitermes grassei* (Isoptera: Rhinotermitidae) in response to sand bulk density and the presence of food. *Insect Sci.* **2007**, *14*, 511–518.
63. Suiter, D.R.; Jones, S.C.; Forschler, B.T. *La biología de las termitas subterráneas del este de los Estados Unidos*; Boletín 1209; University of Georgia: Athens, GA, USA, 2002; 8p.
64. Siqueira, R.; Yamaoka, R.S.; Casao, R., Jr.; Batista de Medeiros, G.; Hamakawa, P.J.; de Souza Ladeira, A. Sistemas de preparo e coberturas vegetais em um solo de Baixa aptidao agrícola. In Proceedings of I Encontro Latino Americano de Plantio Direto na Pequena Propriedade, Ponta Grossa, Rasil, Brazil, 22–26 September 1993; pp. 221–237.
65. Simandl, J. The spatial pattern, diversity and niche partitioning in xylophagous beetles (Coleoptera) associated with *Frangula alnus* Mill. *Acta Oecol.* **1993**, *14*, 161–171.
66. Cogollor, G. Dinámica poblacional de agentes de daño asociados a bosque nativo. In *Agentes de Daño en el Bosque Nativo*; Baldini, A., Pancel, L., Eds.; Editorial Universitaria: Santiago, Chile, 2002; pp. 65–130.

.